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**RED PHOTOLUMINESCENCE
EMISSION OF LASER DYE DOPED
DNA AND PMMA (PREPRINT)**

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and Andrew J. Steckl**



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Red Photoluminescence Emission of Laser Dye Doped DNA and PMMA

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ABSTRACT

DNA and PMMA were doped with the laser dye sulforhodamine 640. Red emission was observed from both dye-doped DNA and PMMA upon photoexcitation. Photoluminescence (PL) emission was studied as a function of dye concentration. The maximum PL intensity of dye in DNA host material is at least 17 times higher than that in PMMA. The DNA host shows higher doping concentration without optical quenching than PMMA does.

Keywords: deoxyribonucleic acid, PMMA, laser dye, photoluminescence

1. BACKGROUND

Polymer materials attracted interest for photonic applications (such as rare earth doped fiber, high speed switcher, etc.) due to their low cost and flexibility.



Fig. 1

Schematic structure of DNA double helix. The diameter is 2.1 to 2.3 nm and the distance between adjacent base pair is 3.4 Å.

While some polymer-based materials gained ground in device applications, the overall progress in device development is still in early stage compared to their inorganic counterparts. This may be due to the fact that most polymeric materials have higher optical loss than most inorganic semiconductor materials used in photonic devices

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fabrication. The high optical loss in organic materials is mainly due to structure scattering from randomly organized locals because of lacking of crystal structure in these materials in general and electro-optical interaction between photons and local molecular groups.

Recent research suggested DNA is a good candidate in polymer materials for photonics applications^{1,2,3}. In previous research, different dyes were studied^{4,5,6,7}. It is believed that the unique double-helix nano structure of DNA plays an important role in intercalating foreign dye molecules and in enhanced optical properties.

In this paper, we compare the effect of dye in DNA and PMMA hosts. The relationship between doping concentration and PL intensity was studied.

2. EXPERIMENT

The raw DNA material is treated with surfactant to change solubility and to improve spin-on film quality. CTMA was used as surfactant in our experiment. Process details such as surfactant reaction and sonication were summarized and recently reported by Heckman, et al.⁸. In this paper, DNA-CTMA of 178,000 Da was used for thin film fabrication. PMMA with M.W. of 120,000 Da was obtained from Sigma-Aldrich.

In our experiments, sulforhodamine 640 laser dye was used. Sulforhodamine 640 is one of the popular rhodamine family dyes and it has the maximum red emission ranging from 600 nm to 640 nm in solvent based laser system and it can also be used in solid state laser system⁹.

DNA-CTMA and PMMA films doped with sulforhodamine found to be uniform and optically transparent.

3. RESULTS AND DISCUSSIONS

DNA-CTMA absorbs in the UV range from 220 nm to 300 nm due to the presence of aromatic nitrogenous bases. A Perkin-Elmer UV-Vis spectrometer was used to measure dye-doped DNA thin film absorption. The absorption peak at 580 nm (Fig. 2) is attributed to sulforhodamine molecules. Because of the low doping concentration, no obvious transmission change for host material was present after the doping.

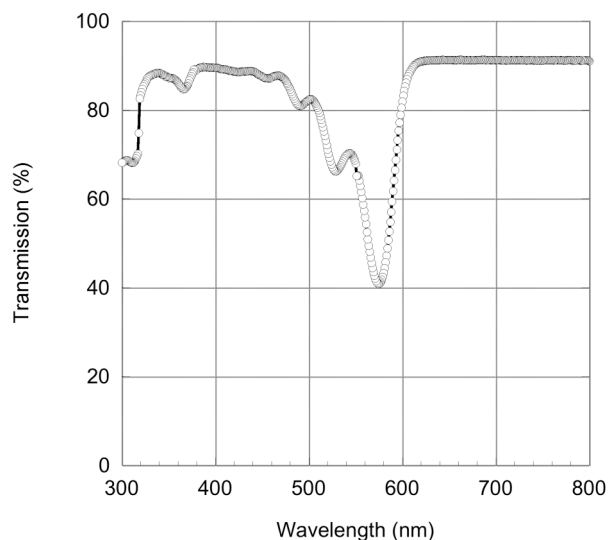


Fig. 2 Transmission spectrum of DNA-CTMA doped with sulforhodamine.

PL measurement was performed with a He-Cd laser at 325 nm. The emission spectra were analyzed by an Acton Research spectrometer equipped with a photomultiplier sensitive in the ultraviolet (UV)-visible spectrum. High-pass filters and dichroic mirrors were utilized to block the laser pump light. The resolution of Acton Research spectrometer for PL measurements was 0.16 nm and PL measurements were performed at 300 K.

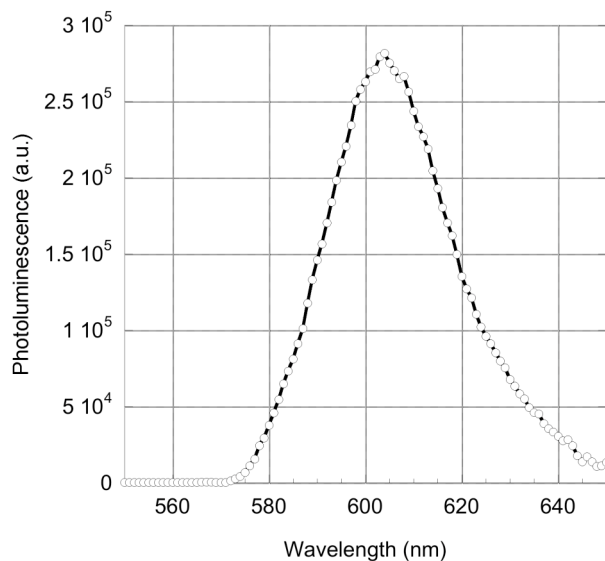


Fig. 3 PL spectrum of sulforhodamine doped DNA-CTMA excited by He-Cd laser.

Fig. 3 shows a typical PL spectrum of emission from sulforhodamine-doped DNA-CTMA. The peak position at 605 nm at maximum emission is consistent with literature report for this specific dye. To determine the doping concentration for maximum PL emission, DNA-CTMA and PMMA samples with different dye concentrations were investigated. The main peak at 605 nm was integrated in order to compare PL emission intensities among different doping concentrations and between two different host materials (Fig. 4).

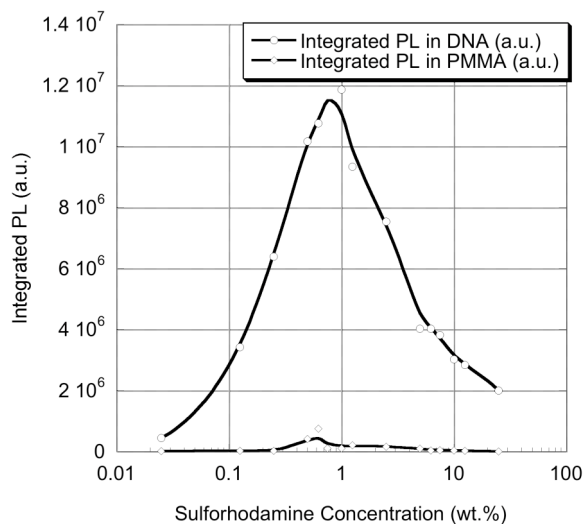


Fig. 4 Integrated PL emission of sulforhodamine in DNA-CTMA and PMMA at different weight concentrations.

The above figure clearly shows that the same amount of dye in DNA-CTMA emits more efficiently than in PMMA. It also shows that around 1 wt% the PL emission reaches its maximum in DNA-CTMA host while in PMMA this concentration is around 0.5 wt%. DNA-CTMA can be doped twice as much as in PMMA. The integrated PL intensity also indicates that the absolute increase of maximum PL from PMMA host to DNA-CTMA host is about 17 times higher.

4. CONCLUSIONS

In summary, we have investigated the doping of DNA and PMMA with the laser dye sulforhodamine. The optimum concentration for sulforhodamine doping into DNA and PMMA was obtained. The DNA host was found to be superior to PMMA in terms of luminescence output.

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REFERENCES

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- 1 J. A. Hagen, J. G. Grote, N. Ogata, J. S. Zetts, R. L. Nelson, D. E. Diggs, F. K. Hopkins, P. P. Yaney, L. R. Dalton and S. J. Clarson, *Proceeding of SPIE* 5351
 - 2 J. A. Hagen, J. G. Grote, N. Ogata, E. Heckman, P. P. Yaney, D. E. Diggs, G. Subramanyam, R. L. Nelson, J. S. Zetts, F. K. Hopkins, and E. W. Taylor, *Proceeding of SPIE* 5554
 - 3 J. G. Grote, E. Heckman, J. A. Hagen, P. P. Yaney, G. Subramanyam, S. J. Clarson, D. E. Diggs, R. L. Nelson, J. S. Zetts, F. K. Hopkins, and N. Ogata, *Proceeding of SPIE* 5621
 - 4 Y. Kawabe, L. Wang, T. Koyama, S. Horinouchi and N. Ogata, *Proceeding of SPIE* 4106
 - 5 T. Koyama, Y. Kawabe and N. Ogata, *Proceeding of SPIE* 4464
 - 6 L. Wang, K. Ishihara, H. Izumi, M. Wada, G. Zhang, T. Ishikawa, A. Watanabe, S. Horinouchi and N. Ogata, *Proceeding of SPIE* 4905
 - 7 D. E. Diggs, J. Hagen, Z. Yu, E. Heckman, F. K. Hopkins, J. G. Grote and A. Steckl, *Proceeding of SPIE* 5934
 - 8 Emily M. Heckman, Joshua A. Hagen, Perry P. Yaney, James G. Grote and F. Kenneth Hopkins, *Applied Physics Letters*, 87, 211115 (2005)
 - 9 F. Salin, G. Le Saux, P. Georges and A. Brun, *Optics Letters*, Vol 14, No 15 (1989)